Selective Averaging of Multiple MR Images

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Introduction

Rapid imaging techniques allow for the generation and manipulation of large MR image sets. Multiple images of a given slice can be averaged to create one image with very high signal-to-noise ratio (SNR). Direct averaging of N images results in an increase in SNR by $\sqrt{N}$, but motion during or between image acquisition results in artifacts and blurring.

We present a method for selectively choosing the raw or image data points to be averaged. Motion between and during data acquisition is statistically recognized and eliminated in the average process.

Method

The selective averaging method (SAM) is an iterative algorithm. The first step involves averaging every data point across all the images used. For each point, the average and standard deviation (SD) are used in the following decision criteria. Any point which is greater than a chosen SD multiple (SDM) from the average is removed before the next iteration. After several iterations, the number of points retained reaches a minimum. The SDM is then decremented and the process is repeated until a new minimum is reached. As a result, only points falling within the range of values are averaged. The SDM range (typically 3.0-1.2) and the SDM decrement value (typically 0.01-0.5) is chosen based upon the desired degree of image sharpness, the desired SNR, and the computing time available.

Results

SAM was compared with direct data set averaging. In two separate studies, fifty gradient-recalled images were generated. The first set of images was of a human head including one eye. The subject was instructed at several instances to move during imaging. The second set was of a beating rat heart.

We defined the equivalent number of images used (N) as the total number points averaged divided by the number of points in one image. Figure 1 illustrates the manner in which SD and N decrease with each successive iteration and decrement in SDM. Figure 2 illustrates the relationship between N and the average SD per point at each SDM. The images obtained from directly averaging had a SNR increase of $\sqrt{50}$. Motion artifacts were greatly decreased, but the edges of the objects that were moving were blurry. The selective averaged images had a SNR increase of $\sqrt{N}$. The motion artifacts were also greatly decreased, but the edges of the moving objects were better defined. A sharper image was therefore achieved by selective averaging at a cost in the SNR directly related to the equivalent number of images retained by SAM. Examples using both raw data and image data will be presented.

Further information from SAM was extracted. An image corresponding to the number of pixels removed from each pixel space after the first iteration, in which all points were used, showed a map of the motion of the object. An image of the standard deviation corresponding to each pixel space highlighted high signal intensity areas and edges of the moving parts of the object.

Conclusion

Using SAM, sharper images can be obtained than with direct averaging, with a moderate loss in SNR. Using both image data and raw data gives good results, but the rationale for applying this technique to raw data is more clear. Artifacts due to sporadic motion are confined to the locations in K-space in which they are collected, while these same artifacts are spread throughout the entire image through the Fourier transform. Therefore, removing outlying points from raw data is more appropriate. For cyclic motion, such as that of the heart, the points in the raw data correspond to different phases of the cardiac cycle. Our algorithm presumably settles on data collected during the most stationary phase.

We are currently exploring statistical techniques to isolate other phases of the cardiac cycle and, thus, perform retrospective gating.

Figure 1

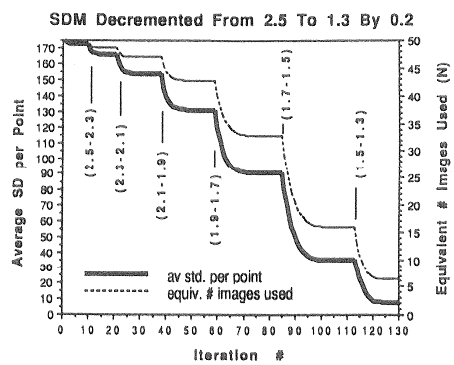

Figure 2